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Research Article

Diversity and Species Composition of Phyco-Periphyton on Some Macrophytes in Rafin Makaranta Stream, Bauchi

Hafsat M. Magaji[1*], A.G. Ezra[2], F.A. Deba[3]

[123]Dept. of Biological Sciences, Faculty of Science, Abubakar Tafawa Balewa University Bauchi, – Nigeria

**Corresponding Author: amsamagaji@gmail.com*

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Abstract— Water quality is essential to human health due to its direct influence on ecosystems and public health. This study analyzed selected physicochemical parameters and the phyco-periphyton assemblage on aquatic macrophytes in Rafin Makaranta Stream, Bauchi, Nigeria, from February to September 2021 at four sampling sites. The objectives were to evaluate the stream's physical, chemical, and biological characteristics. Phyco-periphyton samples were collected by carefully cutting aquatic macrophytes with a sharp razor blade and preserving them in 4% formalin. Standard methods were used to analyze physicochemical parameters, which showed ranges for temperature (24.5 - 34.9°C), pH (7.2 - 8.9), conductivity (0.46 - 0.67 µS/cm), total dissolved solids (338 - 472 mg/L), dissolved oxygen (2.09 - 7.2 mg/L), biochemical oxygen demand (0.66 - 3.67 mg/L), total suspended solids (0.1 - 0.3 mg/L), turbidity (20 - 162 NTU), nitrate (0.2 - 16.7 mg/L), and phosphate (0.1 - 0.9 mg/L). Principal Component Analysis (PCA) indicated that biochemical oxygen demand had the greatest positive environmental impact, followed by total dissolved solids and temperature. Additionally, Pearson correlation showed a positive association between total dissolved solids, temperature, and turbidity, suggesting their combined effect on water quality dynamics. Six macrophytes, including *Nymphaea lotus* (18.18%), *Ludwigia abyssinica* (9.09%), *Hygrophila auriculata* (18.18%), *Pistia stratiotes* (27.27%), and *Typha domingensis* (18.18%), served as essential habitats for the periphyton community. The periphyton identified comprised four classes: Bacillariophyta (6 genera), Chlorophyta (11 genera), Cyanophyta (7 genera), and Euglenophyta (3 genera), with Chlorophyta being dominant at 44%, followed by Cyanophyta (39%), Bacillariophyta (12%), and Euglenophyta (5%). Notable nutrient enrichment indicators, including *Melosira*, *Scenedesmus*, *Oscillatoria*, and *Anabaena*, were observed. Canonical Correspondence Analysis highlighted temperature, total dissolved solids, biochemical oxygen demand, and dissolved oxygen as significant physicochemical factors affecting the structure, composition, and distribution of the periphytic community. Overall, the findings suggest that Rafin Makaranta Stream is impacted by both natural and human-related factors, which influence its algal community and contribute to water contamination. Continued monitoring is recommended to confirm these findings and effectively manage potential environmental impacts.

Keywords— Diversity, Species, composition, phyco-periphyton, Macrophytes.

1. Introduction

Streams are biologically diverse ecosystems in which water quality is influenced by variations in physical structure and chemical composition. Through their ecological roles and interactions with non-living environmental factors, biotic communities help maintain the ecological integrity and health of these systems. Streams serve as habitats for a broad range of biotic assemblages, from micro to macro organisms. The biological structure and function of streams are shaped by the diversity of habitat features and substrates [23][11].

In tropical regions, submerged substrates like stones, plants, and logs in water bodies are typically at least partly covered by periphyton communities. Physicochemical, biological, and hydrological cycles regulate the composition, distribution, and biomass of periphyton species [6]. In most aquatic ecosystems, periphyton consists of a complex mixture of algae, cyanobacteria, heterotrophic microbes, and detritus attached to submerged surfaces [8]. It serves as a crucial food source for invertebrates, tadpoles, and some fish, and it absorbs contaminants from the water, making it a significant indicator of water quality [2].

Periphyton can be used as a model organism to study changes in stream conditions, providing insight into the effects of human pollution and climate change on aquatic systems [17]. Populations within periphyton communities include green algae, diatoms, blue-green algae, heterotrophic bacteria, and fungi, which form attached assemblages within waterways

[13][15]. Due to their rapid generation times and adaptability, these organisms respond quickly to environmental changes within aquatic systems, leading to fast shifts in periphyton communities [18].

Factors such as rising temperatures, varying nutrient levels, predation, and changes in substrate influence periphyton species composition [9][20]. Because periphyton communities can quickly adjust to seasonal changes and human impacts, they provide valuable information on the changing conditions within water systems [4][10]. Periphyton research helps predict how rising water temperatures and nutrient levels, which are significant climate change effects, will impact stream communities. As bioindicators, periphyton offer a cost-effective means of stream monitoring. They show increased diatom biomass at lower phosphorus concentrations, while higher phosphorus levels lead to communities with more green and blue-green algae biomass [19].

Statement of the Problem

As global temperatures rise, stream water temperatures are also affected, which directly impacts periphyton communities. Climate change is known to lead to earlier snowmelt and more intense precipitation events worldwide [21][22]. With increasing global air temperatures, there is a likelihood of more frequent green algae and cyanobacterial blooms [18]. Seasonal shifts in periphyton communities serve as bioindicators of rising water temperatures, allowing for observations of current communities compared to their historical patterns [24]. However, there is limited information on algal diversity in the Rafin Makaranta stream. This study aims to address this gap by assessing the diversity of periphytic algae in the Rafin Makaranta stream, located in Bauchi metropolis.

Objectives of the Study

This study seeks to examine the diversity, composition, and abundance of periphytic algae in the Rafin Makaranta stream, located in Bauchi metropolis, and to provide foundational information on the stream's physicochemical characteristics and trophic status. The specific objectives of the study are:

i. To identify algae species present on aquatic macrophytes.

ii. To assess the physicochemical parameters of the stream.

Justification

Microalgae are capable of performing photosynthesis, they are important to life on earth. It produces about half of the oxygen in the atmosphere and is used for extracting carbon dioxide from the environment simultaneously. Anthropogenic activities are carried out frequently at Rafrin Makaranta stream such as washing, block moulding works, watering of animals, bathing, and fishing. This can lead to the instability of the alga dynamics of the river, little or no work has been carried out to determine the algal diversity of the river. This study will also serve as reference material for future researchers and as a contribution to literature in this field.

2. Related Work

Temperature is a crucial water quality parameter that influences nearly all physical and biological properties of water, thereby impacting its chemistry [12]. Life processes are grounded in complex biochemical reactions that are affected by physical conditions, particularly temperature. As a vital indicator of water quality, temperature affects water's capacity to hold dissolved oxygen, the metabolic rate of aquatic organisms, the rate of photosynthesis and growth in aquatic plants, and the resistance of fish and other stream inhabitants to parasites, disease, and pollutants [16]. Seasonal variations in air temperature, sunlight duration, and solar radiation cause fluctuations in water temperature throughout the year, impacting the self-purification capacity of streams and their sanitary quality [7].

All organisms have a limited tolerance range for stream temperatures, and exceeding these ranges leads to various behavioral and physiological responses. Temperature changes can increase dissolved oxygen levels, raise biological oxygen demand (BOD), and accelerate nitrification processes. Higher temperatures reduce dissolved oxygen availability, making aquatic organisms more susceptible to toxins, parasites, and disease [5]. The combined effects of bright sunlight and temperature also promote the growth of green algae.

3. Theory/Calculation

In a study, [3] reported that periphytic algae showed the greatest richness and density during the high-water period, with 72 taxa recorded compared to 67 taxa in the low-water period. Research also highlights the dominance of Bacillariophyceae among periphyton classes in terms of diversity and density within stream ecosystems [15][17]. Diatoms and other algae, being photosynthetic, rely on nutrient availability for growth and reproduction [22]. The diversity and abundance of periphyton taxa are influenced by various factors, including habitat and substrate types [4]; physical characteristics of substrates such as micro-topography and orientation [14]; light intensity [3]; grazing pressure [19]; seasonal changes [11]; nutrient levels [13]; and temperature [5]. Some periphyton classes, like Cyanophyceae, show increased growth with higher water temperatures and lower alkalinity, conductivity, and hardness [6]. Periphyton is a key component of the food chain and is often the most abundant primary producer in some aquatic ecosystems [21]. Phycoperiphyton and phytoplankton are main primary producers in aquatic systems, and their distribution reflects certain environmental conditions due to the influence of currents and water movements [23]. Numerous studies have cited periphyton communities as indicators of stream health, exploring the effects of biotic and abiotic factors on their composition and abundance. Periphyton plays a significant role in nutrient dynamics, both directly, by nutrient uptake and assimilation, which decreases available nutrients in the water column and sediments, and indirectly, through other regulatory processes [14].

4. Experimental Method/Procedure/Design

Description of Study Area

Rafin Makaranta stream is located in the Bauchi Local Government Area of Bauchi State at a longitude of 10°21'43.6"N and latitude of 9°50'16.3"E. Anthropogenic activities carried out at the sites include farming, irrigation, drinking water, washing, watering of animals, bathing, and fishing.

Collection of Water Samples

All samples for physicochemical analyses were collected in 500 ml plastic bottles with screw caps, in tree replicate from 4 stations between the hours of 7.00 am - 8.00 am, and were transported to biological sciences laboratory ATBU for analysis.

Collection of Algal Specimen

A sampling of algae was carried out by carefully cutting the aquatic macrophytes with a sharp razor blade and this was then transferred to a polythene bag containing distilled water. This was then being shaken vigorously to remove the algal materials as described by [1]. The algal materials were then be transferred into the sampling bottles and preserved with 4% formalin prior to identification.

5. Results and Discussion

List of algal species on aquatic *macrophytes* in Rafrin Makaranta stream

Baccilloriophycea

a. *Cymbella*
b. *Diatom*
c. *Gomphonema*
d. *Melosira*
e. *Navicula*
f. *Synedra*

Class: Chlorophycea

a. *Akistrodemus Facatus*
b. *Chlorella spp*
c. *Closterium*
d. *Cosmerium*
e. *Elakatothink*
f. *Goeeocystis gigas*
g. *Pediastrum*
h. *Scenedesmus*
i. *Sprogyra Spp*
j. *Tetrastrum*

Class: *Cyanophycea*

a. *Aphanothece*
b. *Chrococus turgida*
c. *Gloecocapsa*
d. *Oscillatoria*
e. *Spirulins*
f. *Wodularia*

Class: *Euglenaphycea*

a. *Euglena acus*
b. *Lepocinlis*
c. *Phacus chandata*

The result above shows the various algal species found on aquatic macrophytes in Rafrin Makaranta stream, categorized into different classes: *Bacillariophyceae*, *Chlorophyceae*, *Cyanophyceae*, and *Euglenophyceae. Bacillariophyceae*, commonly known as diatoms, are prominent in the list, with genera like *Cymbella*, *Gomphonema*, *Melosira*, *Navicula*, and *Synedra* identified. These diatoms are known for their intricate silica cell walls and play significant roles in aquatic ecosystems as primary producers. Chlorophyceae, or green algae, are represented by a diverse array of genera such as Chlorella, Closterium, Cosmerium, Scenedesmus, and others. Green algae are crucial contributors to aquatic habitats, contributing to oxygen production and serving as food sources for various organisms. Cyanophyceae, or blue-green algae, include genera like Aphanothece, Oscillatoria, and Spirulina. These organisms are capable of photosynthesis and nitrogen fixation, playing dual roles in nutrient cycling and ecosystem dynamics. Euglenophyceae, represented here by Euglena and other genera, are single-celled organisms known for their flagella and ability to perform photosynthesis when exposed to light. They are commonly found in freshwater environments and are indicators of water quality.

Table 1: Monthly variation of some physical and chemical properties of aquatic macrophytes in Rafin Makaranta stream

Month	Location	DO (mg/l)	BOD5	pH	Temperature (°C)	EC (µs/cm)	TDS (mg/l)	TSS (mg/l)	Turbidity (NTU)	NO3 (mg/l)	N (mg/l)	P (mg/l)	PO4 (mg/l)
February	A1	5.61	1.65	7.2	24.5	0.48	328	0.3	29	23.9	5.4	0.2	0.01
March	A1	5.61	1.33	7.5	26.3	0.6	433	0.3	104	12.8	2.9	0.04	0.12
April	A1	4.89	2.79	7.3	34.7	0.68	490	0.3	39	25.1	5.7	0.03	0.1
May	A1	3.28	2.57	8.1	29.9	0.62	447	0.3	25	55.6	12.6	0.07	0.22
June	A1	4.24	0.74	8.2	28.9	0.55	399	0.3	39	34.8	7.9	0.5	0.14
July	A1	5.61	1.31	7.8	26.6	0.67	484	0.3	50	39.5	8	0.7	0.16
August	A1	6.2	3.1	8.4	28.1	0.54	387	0.1	20	36.2	8.3	0.1	0.2
September	A1	5.6	2.8	8.6	28.5	0.47	340	0.1	5	32.2	6.8	0.1	0.3

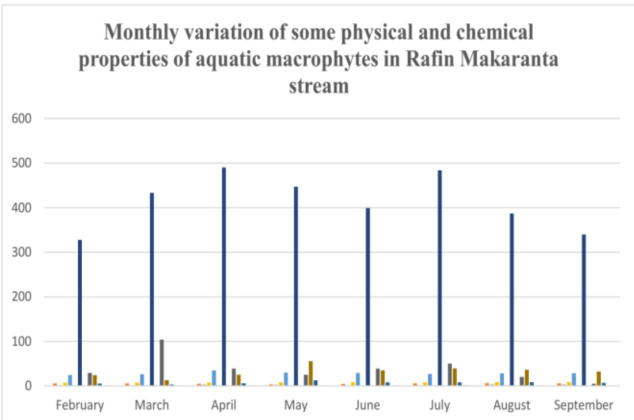

Figure 1: Monthly variation of some physical and chemical properties of aquatic macrophytes in Rafin Makaranta stream

Relationships between physicochemical parameters and the phytoplankt on community

The Canonical Correspondence Analysis (CCA) with ANOVA Pr(>F) indicated that variables such as temperature ($p = 0.005$), TDS ($p = 0.005$), BOD ($p = 0.005$), and DO ($p = 0.010$) had a significant impact on the structure and distribution of the phytoplankton community in Rafrin Makranta stream. Additionally, turbidity, nitrate, and pH showed a marginal impact. The physicochemical parameters predominantly influenced species such as Chlorococcus, Scenedesmus, Oscillatoria, Phacus, and Elakatothnix (Figure 4.2.1).

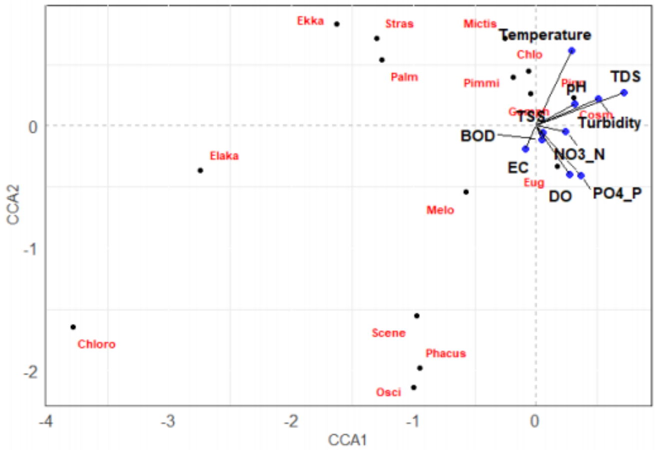

Figure 4.2.1. CCA biplot of algal species in relation to physicochemical properties in Rafrin Makaranta stream.

Discussion

The diversity and species composition of *phyco-periphyton* on *macrophytes* in Rafin Makaranta Stream, Bauchi, represent a significant ecological study, contributing to our understanding of freshwater ecosystems. Similar studies by various authors in recent years have underscored the importance of *periphyton* communities in aquatic environments. For instance, [16] highlighted the role of *macrophytes* as substrates for *periphyton* colonization, influencing community structure and nutrient dynamics. Their findings align with the observations in Rafin Makaranta Stream, where diverse *macrophyte* species likely support varied *periphyton* communities.

In contrast, [24] emphasized the influence of environmental variables such as water flow rate and nutrient availability on *periphyton* diversity and composition. These factors could explain variations in *phyco-periphyton* observed among different *macrophyte* species within the same stream. Such variability may also reflect broader ecological patterns observed in other freshwater systems studied by [4] and [22]. Furthermore, the temporal dynamics of periphyton development, as discussed by [10], indicate seasonal fluctuations that could impact community structure on macrophytes in Rafin Makaranta Stream. These fluctuations are crucial to consider when interpreting the species composition data, as they provide insights into the resilience and adaptive strategies of periphytic organisms in response to environmental changes. [17] highlighted that temperature variations significantly impact water quality parameters such as dissolved oxygen and pH, corroborating the current study's findings on their interrelationships.

Similarly, [9] emphasized the critical role of electrical conductivity in assessing water quality, noting its correlation with dissolved solids and nutrients like nitrogen and phosphorus, which aligns with the results reported here. [18] and [4] underscored the ecological implications of high turbidity and suspended solids in aquatic environments, suggesting adverse effects on aquatic life and biodiversity. These findings are consistent with the current study's observations regarding turbidity and total suspended particles. Moreover, the significant findings from the ANOVA analysis in this study (Table 9) are supported by literature indicating that variations in physio-chemical parameters across different stations or times reflect underlying environmental conditions and anthropogenic influences [4], [8].

6. Conclusion and Future Scope

The study on the diversity and species composition of phyco-periphyton in Rafin Makaranta Stream encountered several challenges and limitations that have impacted the overall findings and the achievement of our research objectives. Contrary to our expectations, the study revealed a relatively low diversity of algal species on the aquatic macrophytes in the stream. This limited diversity may indicate that Rafin Makaranta Stream faces ecological stressors that negatively affect the algal community.

Recommendations

The conclusions led to the following suggestions being made:

1. Long-Term Monitoring: Establish a long-term monitoring program to track changes in the algal community over time. This will help identify trends and seasonal variations, as well as detect any emerging issues or stressors affecting the stream ecosystem.
2. Environmental Impact Assessment: Assess the impact of external factors, such as pollution sources and weather events, on the stream ecosystem. Identifying and mitigating sources of pollution can contribute to the overall health of the stream and its algal community.

Conflict of Interest

This unique replica is not being considered for publishing anywhere and has not been disseminated. There are no conflicts of interest to declare as a result.

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Author Contributions

Each author made an equal contribution to this research thesis. They all looked over and verified the original manuscript's final draft.

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